# PREPRODUCTION INITIATIVE
# HELICOPTER TRANSMISSION FLUID PURIFICATION UNIT
# FINAL REPORT

## NAS PATUXENT RIVER, MD
## NAS JACKSONVILLE, FL

## 1.0 INTRODUCTION

The U.S. Navy has adopted a proactive and progressive position toward protecting the environment and complying with environmental laws and regulations. Rather than merely controlling and treating hazardous waste by end-of-the-pipe measures, the Navy has instituted a program for pollution prevention (P2) to reduce or eliminate the volume and toxicity of waste, air emissions, and effluent discharges.

P2 allows the Navy to meet or exceed current and future regulatory mandates and to achieve Navy-established goals for reducing hazardous waste generation and toxic chemical usage. P2 measures are implemented in a manner that maintains or enhances Navy readiness. Additional benefits include increased operational efficiency, reduced costs, and increased worker safety.

The Navy has truly set the standard for the procurement and implementation of P2 equipment. The Chief of Naval Operations (CNO), Environmental Protection, Safety, and Occupational Health Division (N45) established the P2 Equipment Program (PPEP), through which both NAVAIR Lakehurst and the Naval Facilities Engineering Service Center (NFESC) serve as procurement agents under the direction of N45. P2 equipment is specified and procured under two complementary initiatives: the Preproduction Initiative (i.e., technology demonstration) and the Competitive Procurement Initiative. The Preproduction Initiative directly supports both the Navy Environmental Leadership Program (NELP) for P2 shore applications and the P2 Afloat program, which prototypes and procures P2 equipment specific to the needs of ships.

This report provides an analysis of the procurement, installation, and operation of P2 equipment under the Preproduction Initiative. Technology demonstrations and evaluations are primarily performed under the PPEP Preproduction Initiative at two designated NELP sites—Naval Air Station (NAS) North Island and Naval Station (NS) Mayport. Additional sites, such as NAS Jacksonville and NAS Patuxent River, have been added as required to meet specific mission goals. The program involves defining requirements, performing site surveys, procuring and installing equipment, training operators, and collecting data during an operational test period. The equipment is assessed for environmental benefits, labor and cost savings, its ability to interface with site operations, and its ability to perform the required functions.

## 2.0 BACKGROUND

The SH-60 aircraft went through an Oil Life Extension Program from 1990-1993. The program, conducted by the Fuels and Lubricants Division (AIR-4.4.5) at NAVAIR PAX and the SH-60 Aircraft PMA, extended the oil drain time interval for the main transmission system from 450 to 900 flight hours. Since then, the oil drain time interval has been extended again—to 1000 flight hours. The Lubricants group within the Fuels and Lubricants Division is the Cognizant Field Activity (CFA) for all Navy aviation propulsion system lubricant matters. The Lubricants group also has the responsibility for accepting and certifying for use all aviation lubrication-related equipment and procedures. To further reduce oil waste and oil procurement resulting from oil changes, PPEP examined the possibility of recovering drained transmission oil for reuse.

### 2.1 Current U.S. Navy Helicopter Transmission Oil Change Practices

Currently, used oil is drained from the helicopter transmission system after a specified number of flight hours or as required by specific maintenance actions. After it is drained, the transmission system is filled with new oil and returned to operation. On some occasions the transmission is drained again after a short (non-flying) run to circulate the oil (e.g., when a maintenance action or oil analysis results indicate that a flush of the system is recommended). The spent oil must then be disposed of (either as hazardous or used oil waste, depending on local regulations and procedures). Because both the contaminated oil and any oil used to flush the system must be discarded, the total volume of waste generated during one oil change can be as much as twice the capacity of the transmission system. For example, the SH-60 main transmission holds approximately 7.5 gallons of oil; therefore, as many as 15 gallons of waste oil can be generated and disposed of during any given oil change. Following flushing, the system is filled with new oil and returned to operation. In addition to the main transmission, the intermediate gearbox (approximately 1 quart) and the tail gearbox (approximately 1½ quarts) are drained (flushed when necessary) and refilled on their own schedule (approximately 450 flight hours). This requirement results in approximately 1 ¼ to 2 ½ additional gallons of waste oil being generated every 900 flight hours.

The primary contamination problem of the helicopter transmission oil is its tendency to absorb water, which subsequently breaks down the properties of the transmission oil. Water also increases the potential for corrosion of the gearbox components. Water can enter the transmission system through physical intrusion as well as through condensation of atmospheric humidity. When a helicopter is operating over water or at sea, water intrusion—more specifically, corrosive saltwater intrusion—is an even greater possibility.

### 2.2 System Selection

PPEP proposed a fluid purifier unit to remove free and emulsified water and particulates from the drained oil. The purification and subsequent reuse of used transmission oil would reduce waste generation and, potentially, operating costs for both shipboard and land-based aircraft. For simplicity, the use of the purifier during this evaluation was limited to oil drawn from the main gearbox since the volume in the tail/intermediate gearbox is small (too small for significant data collection) and the oil is replaced on a separate cycle.

## 3.0 Helicopter Transmission Fluid Purification Unit Test Program

PPEP sought to demonstrate a portable oil filtering system capable of removing water and particulates from DOD-L-85734 (helicopter transmission oil) without damaging the fluid properties. Ultimately, the reclaimed oil would be made available for reuse (following verification of quality) in aircraft, but this will require aircraft PMA approval. ***Purified or waste oil <u>WAS NOT</u> reused in aircraft during this evaluation.*** Due to the safety of flight consequences of reclaiming helicopter transmission oil, this PPEP project was conducted in three phases.

Phase I of the Helicopter Transmission Fluid Purification Unit (HTFPU) Preproduction Initiative consisted of laboratory testing of the selected unit at the NAVAIR Fuels and Lubricants Division laboratory (AIR-4.4.5) at NAS Patuxent River. After the laboratory verified that the unit performed adequately, an additional unit was procured under Phase II for field testing, which commenced at NAS Jacksonville. Under Phase III, the field unit was shipped to NAVAIR Lakehurst, where efforts are ongoing to test water-spiked samples, determine filter life, and obtain approvals from aircraft platform managers for use of the unit. Additionally, plans are underway, utilizing the unit at AIR-4.4.5, to test purified transmission oil in NAVAIR's helicopter transmission test cell. AIR-4.4.5 laboratory personnel will collect data (e.g., wear measurements, temperature increases, etc.) to determine if the purified transmission oil has any potentially adverse effect on the test transmission and/or engine components. ***At no point during any of these phases was purified oil returned to any aircraft. After purification and lab analyses, the oil was handled and disposed of in accordance with local procedures. This protocol will continue throughout the remainder of Phase III.***

## 4.0 EQUIPMENT DESCRIPTION

### 4.1 Vendor Selection

After extensive vendor searches were conducted, the VP30-1S portable filtering system, manufactured by Allen Filters, Inc., was selected for evaluation. Based on requirements for testing, one unit was provided for NAS Patuxent River and, after completion of the NAS Patuxent River test program, a second unit for NAS Jacksonville was provided.

### 4.2 System Components

The Allen VP30-1S portable filtering system is comprised of the following components:

- Two cartridge filters for removal of trace quantities of emulsified and free water and particulates down to 0.5 micron (Note: manufacturer claim – not substantiated).
- One Viking positive displacement rotary gear pump rated at 30 gallons per hour

- One ¼-hp motor, completely enclosed, fan-cooled, rated for 1725 revolutions per minute (rpm), 115/230V, 60 Hz, and single-phase power supply (currently wired for 120V)
- ½" National Pipe Thread (NPT), schedule 40, carbon steel piping
- Two hoses with abrasion-resistant covers and quick-release fittings for suction and discharge of fluid
- Power cable
- Portable steel cart on which components are positioned.

### 4.3 Method of Operation and Modifications Made During Evaluation Period

The HTFPU is designed to process 30 gallons of oil per hour. Depending on the filter cartridges selected, the system can remove solids, sludge, and/or free and emulsified water by pumping the contaminated oil through the filters.

To operate the unit, the user must have two containers for handling the oil (one container for the as-drained, contaminated oil and one container for the purified oil). For an H-60 main transmission (any variant), each container must be capable of holding 15 gallons of oil (i.e., the volume of the main gearbox and one flush). The as-drained container is connected to the inlet of the HTFPU and the purified oil container is connected to the outlet. For purification, the oil passes through the HTPFU a number of times.

After the initial pass through the HTFPU, any subsequent passes are unlikely to significantly reduce particulate contamination; however, repeated passes will remove larger quantities of emulsified water from the oil. The optimum number of passes depends in part on the quantity of free and emulsified water in the oil and the condition of the filters. Based on data collected during Phase I, AIR-4.4.5 determined that the optimum number of passes through the HTFPU is three. Additional passes beyond three did not significantly improve the condition of the oil.

The HTFPU has a holdover volume of 6 gallons of oil that remain inside the unit after each use. It was initially decided to process the oil in batches to eliminate possible cross-contamination between composite volumes and to isolate any possible effects of the HTFPU on the oil. To keep each batch of oil discrete, this holdover volume was drained between batches. Due to the inconvenient location of the drain port—approximately 6 inches above the ground—it was necessary to suspend the HTFPU from a portable lift to adequately drain the holdover volume. Based on data collected during Phase I testing, AIR-4.4.5 determined that it was unnecessary to drain the holdover volume from the HTFPU between batches provided the same type of oil was being purified in each batch.

During Phase I, the HTFPU was modified for ease of use by installing several fittings and ball valves on the inlet and outlet hoses and on the drain port. Installing ball valves in these locations eliminated both the possibility of oil leaking out of the hoses when handling the unit and the need to prime the pump before each use.

At the start of Phase II testing, a new VP30-1S HTFPU unit was delivered to NAS Jacksonville and modified onsite to include the recommended fittings and ball valves. In addition, a dip tube was added before the inlet hose valve, and a shorter discharge tube was added after the outlet hose valve. Furthermore, during this phase of the evaluation, the handcart on which the unit is situated was modified by removing 1 ½ inches from the cart support leg. This change was made to improve the balance of the HTPFU and make it less susceptible to tipping over. The unit was still inadequately balanced; during Phase II testing it fell over, bending the handle and the air vent at the top. This configuration is unacceptable for fleet use. The current off-the-shelf configuration will be changed to a more stable configuration before the unit is deployed to the fleet.

### 4.4 Implementation Requirements

The specifications and requirements (as supplied by the manufacturer) for the Allen Filter VP30-1S Fluid Purifier include:

- Dimensions (width x length x height): 19” x 19” x 46”
- Weight: 145 pounds
- Electrical Requirements: Access to 115-volt outlet
- Portability: Equipped with a portable steel cart capable of supporting the full weight of the equipment.

### 4.5 Overall Benefits

The HTFPU has several potential benefits, including:

- Reducing the quantity and cost of oil disposal
- Reducing the requirement for procurement of new oil
- Extending helicopter drive system life.

## 5.0 DATA ANALYSIS

To date, data have been collected during Phases I and II. Data were collected during the laboratory testing phase using the Purification Data Sheet. Data were collected during the field test phase using the Oil Purifier/Water-in-Oil Analyzer Data Sheet and the Maintenance and Repair Log. These data sheets were provided with the project Test Plan.

Phase I data were collected between May 1999 and September 1999. Phase II data were collected between January 2002 and March 2004. Phase III data collection is currently ongoing; results will be included in this report at a future date as an addendum.

During the Phase I laboratory verification, AIR-4.4.5 personnel sought to determine the effectiveness of the unit in removing water and particulates from transmission oil, as well as whether the unit degraded the oil’s properties in any way. Used transmission oils sent to AIR-4.4.5 from fleet operations were used for purification testing. After being tested for mission requirements, several fleet samples were combined to form a larger, composite oil volume. Several composite volumes were generated and purified as distinct batches. Each composite volume was subjected to several physical and analytical tests before, during, and after purification. The following tests were performed on all samples:

- Viscosity
- Total Acid Number (TAN)
- Sediment Testing
- Water Content
- Wear Metal Content.

In addition, the following tests were performed on the unpurified and the final purified samples:

- Foam Testing
- Flashpoint
- Oxidation/Corrosion
- Thermal Stability/Corrosivity
- Gas Chromatography
- High Pressure Liquid Chromatography
- 4-Ball Wear Testing.

A description of each of these tests is available for reference in the HTFPU Preproduction Initiative Test Plan and in AIR-4.4.5 Report 00-001, "Initial Evaluation of Oil Purification Unit for DOD-L-85734 Helicopter Transmission Lubricant" dated 13 February 2000. The results of these tests and conclusions regarding Phase I testing are found in the AIR-4.4.5 report and in Section 5.1.1.1 (below).

During Phase II, used transmission oil drained from the main gearboxes of SH-60 aircraft was collected and individually purified by NAS Jacksonville personnel using the HTFPU. Samples of the as-drained and purified oils were drawn, labeled, and sent to AIR-4.4.5 for verification that the purified oil met the specifications for DOD-L-85734 and to validate proper operation of the unit in a fleet environment. Personnel were also responsible for collecting the operational and performance data necessary to determine the cost-effectiveness, reliability, and ease of use of the HTFPU in the field. The results of these tests and conclusions regarding Phase II testing are presented in Section 5.1.1.2 (below).

It should be noted that during Phase II of this project, NAS Jacksonville personnel also had access to a Pall WSO4 water-in-oil analyzer that was being tested under a related PPEP Preproduction Initiative Project. This handheld water sensor was used to determine the concentration of water in the "as-drained" oil and the purified oil. It may be a useful tool for providing users and maintainers in the field with a better "feel" for the "health" of the oil. With coordination and concurrence from the Navy Oil Analysis Program and the appropriate PMA, use of the water sensor may also reduce the number of oil samples that require laboratory water content analysis.

As part of Phase III, NAVAIR Lakehurst will spike additional samples of transmission oil with varying quantities of water to evaluate the HTFPU against extreme values of water content (current fleet limit is 1,000 ppm for oil in an operating gearbox). The purification of the spiked samples will also aid in determining the expected filter life and the mechanism of filter failure. Although the manufacturer recommends changing the filters when the differential pressure across the filter reaches 10 psig, filter effectiveness may decrease differently in relation to water saturation or dirt accumulation. Therefore, it is important to determine when and if such degradation in effectiveness occurs in order to develop Navy application-specific maintenance procedures for filter change. Pending favorable results from Phase III, AIR-4.4.6 (Propulsion Drive System) has expressed interest in performance testing purified oil in its helicopter transmission test cell, which is an actual aircraft gearbox (a non-Ready for Issue test asset), to determine if there are any negative effects on gearbox and/or engine components. NAVAIR Lakehurst will also proceed to seek PMA approvals for use of oil purified using the HTFPU in a limited number of test aircraft.

## 5.1 Quantitative Analysis

### 5.1.1 *Sampling Data*

#### 5.1.1.1 Phase I Sampling Data and Results

During Phase I, three test events were performed, and AIR-4.4.5 analyzed several samples from each event. Each test event used a composite of approximately three SH-60 main gearbox samples blended together in a 15-gallon drum. Several samples were analyzed from each test event (i.e., before purification, after pass 1, after pass 2, after pass 4, and after pass 6). Physical and analytical tests include those listed in Section 3 above, and results were compared to the specifications for DOD-PRF-85734A as well as for virgin oil from a typical supplier. Section 4.0 of AIR-4.4.5 Report 00-001 discusses the overall results of each test. At this time, it was determined that three passes through the HTFPU are required to reduce the water content to at or below typical acceptable fleet conditions. Particulates were reduced similarly, although the size of the remaining particulates was larger than the manufacturer's claim. The HTFPU did not remove the transmission oil additive package, nor did it appear to adversely affect the properties of the oil. Tables 1 and 2 provide the results of water content and sediment (particulate) testing, respectively.

**Table 1**
**Phase I Water Content Results**

| Composite Sample ID | Unpurified (ppm) | 1 Pass (ppm) | 2 Passes (ppm) | 4 Passes (ppm) | 6 Passes (ppm) |
|---|---|---|---|---|---|
| 1 | 828 | 159 | 93 | 121 | 70 |
| 2 | 515 | 115 | 96 | 86 | 158 |
| 3 | 682 | 290 | Not tested | Not tested | Not tested |

It should be noted that oils meeting DOD-PRF-85734A have a typical maximum water concentration of between 300 and 600 ppm after brief exposure to ambient air. Both composite samples 1 and 2 showed reductions in water content of approximately 80% after the first pass. Composite sample 3 was purified and tested several months after the first two composite samples, during which time the HTFPU was idle. The reduced performance may be due to the filters absorbing moisture from ambient air or from residual oil present in the unit. This is an indication of the importance of determining the maximum amount of water that the filters can hold without compromising effectiveness—a determination currently expected during Phase III.

**Table 2**
**Phase I Sediment Concentration Results**

| Composite Sample | Unpurified (mg/L) | 1 Pass (mg/L) | 2 Passes (mg/L) | 4 Passes (mg/L) | 6 Passes (mg/L) |
|---|---|---|---|---|---|
| 1 | 28 | 6 | 4 | 4 | 5 |
| 2 | 3.1 | 1.9 | 1.7 | 1.8 | 1.7 |
| 3 | 46 | 30 | Not tested | Not tested | Not tested |

It should be noted that oil meeting DOD-PRF-85734A has a maximum limit of 10 mg/L and that virgin oil typically has sediment concentrations of approximately 0.54 mg/L. For composite samples 1 and 2, testing seemed to indicate that the majority of the particulates were removed after a single pass through the unit, with subsequent passes resulting in very minor continued reduction.

Purification of each sample was performed with six passes through the HTFPU (per manufacturer recommendations), with lab sampling occurring after a specified number of passes. It was determined that running the oil through the HTFPU more than three times provided no additional improvement in oil condition. Therefore, it is recommended that the oil be processed through the HTFPU three times before reuse.

Overall results showed that the purifier was able to reduce the water and the particulate content, although the manufacturer’s claim to remove particulates down to 0.5 micron was not accurate. The unit did not remove or negatively influence the oil’s additive package or overall performance.

#### 5.1.1.2 Phase II Sampling Data and Results

Phase II testing occurred at NAS Jacksonville. Five test events took place at NAS Jacksonville in January and August 2002. Each test event processed a 5-gallon sample of oil through the HTFPU with three passes and took approximately 30 minutes to purify. In each case, NAVAIR Lakehurst personnel assisted NAS Jacksonville personnel with the testing. Samples taken from each test event were sent to AIR-4.4.5 for physical and analytical testing. Table 3 presents the test results, and Table 4 presents a comparison between the specification, typical results for new oil, and the purified and unpurified results.

**Table 3**
**Phase II HTFPU Oil Analysis Results**

| Test | Average Unpurified | Average Purified | Average Difference |
|---|---|---|---|
| 1. Viscosity (cSt) at 40C, min | 26.55 | 26.65 | 0.10 |
| 2. Viscosity (cSt) at 100C | 5.21 | 5.22 | 0.01 |
| 3. TAN (mg), max | 0.56 | 0.34 | -0.22 |
| 4. Water content (KF) | 595.84 | 101.18 | -494.66 |
| 5. Sediment, max (1.2 microns) | 9.54 | 4.9 | -4.64 |
| 6. Ash, maximum | 1.88 | 0.89 | -0.99 |
| 7. Foam maximum | | | |
| a. Sequence II (ml/mg/min) | 20/0/0.63 | 19/0/0.53 | |
| b. Sequence III (ml/mg/min) | 17.25/4.33/3.02 | 18/1.25/0.89 | |
| 8. Corrosion oxidation stab. | | | |
| a. Viscosity change, % | 25.81 | 24.53 | -1.18 |
| b. TAN change, max | 0.43 | 0.57 | 0.15 |
| c. metal weight change, max | | | |
| - steel | 0.005 | 0.008 | 0.003 |
| - silver | 0.103 | 0.053 | -0.05 |
| - copper | 0.263 | 0.241 | -0.022 |
| - aluminum | 0.004 | 0.014 | 0.01 |
| - magnesium | 0.008 | 0.004 | -0.004 |
| d. Contamination (10 microns) | 1.737 | 0.707 | -1.03 |
| 9. Trace metal content, maximum | | | |
| - iron | 1.96 | 1.16 | -0.8 |
| - silver | 0.52 | 0.24 | -0.28 |
| - aluminum | 0.48 | 0.44 | -0.04 |
| - chromium | 0.22 | 0.20 | -0.02 |
| - copper | 0.20 | 0.20 | 0 |
| - tin | 4.66 | 4.32 | -0.34 |
| - magnesium | 1.42 | 1.42 | 0 |
| - nickel | 0.2 | 0 | -0.2 |
| - titanium | 0.24 | 0.32 | 0.08 |
| - silicon | 2.12 | 1.98 | -0.14 |
| - zinc | 0.44 | 2 | 1.56 |
| - lead | 0 | 0 | 0 |
| - molybdenum | 0 | 0 | 0 |
| - phosphorous | 1746.2 | 1546 | -200.2 |

The average difference between the unpurified samples and the purified samples shows an overall improvement in oil composition. There were slight changes in the viscosity of the sample due to the filtration process. Testing indicated that approximately 48% of the particulates were removed from the unpurified oil and an 83% of the water content was reduced from the unpurified oil to the purified oil.

**Table 4**
**Phase II Comparison of Unpurified to Purified Oils to Specification and Typical New Oil**

| Test | Specification Limit | Typical New Oil | Average Unpurified | Average Purified |
|---|---|---|---|---|
| 1. Viscosity (cSt) at 40C, min | 23.0 | 26.84 | 26.55 | 26.65 |
| 2. Viscosity (cSt) at 100 C | 4.90 to 5.40 | 5.24 | 5.21 | 5.22 |
| 3. Total Acid Number (mg/g), max | 0.75 | 0.4 | 0.56 | 0.34 |
| 4. Water Content KF (ppm) | N/A | 300 | 595.84 | 101.18 |
| 5. Sediment (mg/l), max, (1.2 micron) | 10.0 | 7.7 | 9.54 | 4.9 |
| 6. Ash (mg/l), max | 1.0 | 0.7 | 1.88 | 0.89 |
| 7. Foam: max | | | | |
| a. Sequence II (ml/mg/min) | 25/0/1.00 | 10/0/0.08 | 20/0/0.63 | 19/0/0.53 |
| b. Sequence III (ml/mg/min) | 25/0/1.00 | 10/0/0.10 | 17.25/4.33/3.02 | 18/1.25/0.89 |
| 8. Corrosion Oxidation Stab. | | | | |
| a. viscosity change, % | 0 to 30% | 24.87 | 25.80 | 24.53 |
| b. TAN change, max | 2.0 | 0.42 | 0.43 | 0.57 |
| c. metal weight change, max | mg/sq cm | | 0 | 0 |
| - steel | +/- 0.2 | 0 | 0.005 | 0.008 |
| - silver | +/- 0.2 | -0.02 | 0.103 | 0.053 |
| - copper | +/- 0.4 | -0.17 | 0.263 | 0.241 |
| - aluminum | +/- 0.2 | 0 | 0.004 | 0.014 |
| - magnesium | +/- 0.2 | 0.03 | 0.008 | 0.004 |
| d. contamination (10 micron) | 50 mg/100 ml, max | 0.25 | 1.737 | 0.707 |
| 9. Trace Metal Content, max | | | 0 | 0 |
| - iron | 2 | 0 | 1.96 | 1.16 |
| - silver | 1 | 0 | 0.52 | 0.24 |
| - aluminum | 2 | 0 | 0.48 | 0.44 |
| - chromium | 2 | 0 | 0.22 | 0.20 |
| - copper | 1 | 0 | 0.20 | 0.20 |
| - tin | 11 | 5 | 4.66 | 4.32 |
| - magnesium | 2 | 0 | 1.42 | 1.42 |
| - nickel | 2 | 0 | 0.20 | 0 |
| - titanium | 2 | 1 | 0.24 | 0.32 |
| - silicon | 10 | 0 | 2.12 | 1.98 |
| - zinc | 2 | 0 | 0.44 | 2 |
| - lead | 2 | 0 | 0 | 0 |
| - molybdenum | 3 | 0 | 0 | 0 |
| - phosphorous | None/report | 1750 | 1746.2 | 1546 |

It should be noted that because the oil change interval is designed to remove used oil from the transmission before the oil becomes unacceptably contaminated, it is not surprising that the unpurified oil met specification. Some additional comments on the data presented in Table 4 are presented below.

- The average unpurified oil for the TAN was within specification limit. After being filtered through the HTFPU, the average TAN of the purified oil was improved further.

- There is no specification limit given for water content in oil. Compared to the new oil sample, the average unpurified oil sample had a higher water reading. After being filtered through the HTFPU, the average purified oil sample had a reduction in water content, therefore improving the quality of the oil and minimizing the potential for corrosion. It should be noted that DOD-L-85734 will absorb water upon exposure to air and during handling and use. Therefore, it is expected that the water content in the purified oil will increase with exposure to air and during handling and use in the same way that the water content in new oil increases.

- With the sediment test, the average unpurified oil was within the specification limit. The HTFPU did reduce the quantity of sediment in the purified oil further within the specification limit, thus increasing the quality of the oil.

- In the case of the ash test, the average unpurified oil was not within the specification limit. Using the HTFPU to filter the oil brought the average purified oil sample to within specification limits suitable for use in SH-60s.

- Trace wear metal contents were, on average, within specification requirements for both purified and unpurified samples. On average, the concentrations of wear metals for both purified and unpurified oil samples were within specification limits. In general, the concentration of wear metals in the purified samples was lower than the concentration of wear metals in the unpurified samples. However, the low concentrations found in both the purified and unpurified samples are very close to the method’s detection limit. In these circumstances, changes of a few parts per million are not significant.

In conclusion, samples taken after the third pass through the HTFPU indicated an overall improvement to the oil specification limits. Therefore, the purified oil did meet the requirements for reuse based on TAN, water content, sediment, ash, and corrosion oxidation stability. The HTFPU had a positive effect on the cleanliness of the oil samples tested.

It should be noted that the age of the filter might have an effect on the efficiency and effectiveness of the HTFPU. Testing of the filter life and continued effectiveness of the HTFPU is scheduled to occur in Phase III.

### 5.1.2 *Operational Data*

NAS Jacksonville hosts five HS helicopter squadrons, each with six aircraft. Each squadron's complement includes aircraft in a variety of configurations (e.g., four SH-60s and two HH-60s); however, the drive system and maintenance requirements are the same across all variants. While ashore, each helicopter flies an average of 45 hours per month. At this rate, the oil in the main transmission of each helicopter is changed approximately every other year, while the oil in the intermediate/tail gearbox is changed approximately once every 10 months. During a squadron's detachment, each aircraft may fly as many as 500 hours per month. At this rate, each aircraft's main transmission will require six oil changes per year, and each aircraft's intermediate/tail gearbox will require 12 oil changes per year.

Based on the limited testing conducted at NAS Jacksonville, setup and cleanup of the HTFPU takes approximately 10 minutes. The time required to run 5 gallons of oil through the unit three times is approximately 20 minutes. Thus, total operational time using the HTFPU is at most 30 minutes longer than the current procedure because the time to drain and refill the transmission and gearbox is the same under either method. It should be noted that if larger volumes of oil are processed simultaneously, the overall increased labor would be reduced because there is no need to repeatedly set up and clean up the unit between volumes.

### *5.1.3 Cost Analysis*

The cost analysis evaluated two situations for this project. The situation considered an ashore location such as NAS Jacksonville with up to 30 H-60 (all variants) helicopters; however, not all squadrons will be present at the same time. For purposes of the cost analysis, the presence of three squadrons totaling 18 aircraft, each flying 45 hours per month, was assumed. The second situation considered a detachment with six H-60 helicopters (all variants), each flying 150 hours per month. In addition, the following assumptions were made for both situations:

- The main and intermediate/tail gearboxes would be flushed once every six oil changes due to maintenance actions.
- New oil is required once every four oil changes (i.e., a given volume of oil may be purified and reused up to three times before disposal).
- The procurement cost of new oil is $17.45 per gallon.
- The cost of analysis for each oil sample is $10.
- The disposal cost of used oil (with water) is $0.60 per gallon.
- The disposal cost of oil-contaminated solids is $1.20 per pound.
- Since the requirement of changing the oil is not eliminated, the labor required to change and flush the main transmission and intermediate/tail gearbox is the same for both the previous method and the PPEP method. Therefore, these costs were not included in this analysis. However, the additional labor associated with purifying the oil under the PPEP method was included in each analysis.

Based on these assumptions, using the HTFPU at ashore locations will result in annual savings of approximately $784 per year, with a ten-year return on investment of approximately $3,495 and a break-even point of 5.54 years.

Based on the same assumption, using the HTFPU during detachments will generate a 10-year return on investment of about $4,767 and a break-even point of approximately 4.75 years. This difference is due primarily to increased flight hours generating more frequent oil changes, thus increasing the volume and costs of oil procured and disposed of by the detachment. It should be noted that this analysis does not account for the reduced logistics burden achieved by purification and reuse of the helicopter transmission oil (i.e., the procurement and storage aboard a carrier of more than 100 gallons of new oil can be eliminated each year).

## 5.2 Qualitative Analysis

### *5.2.1 Installation*

Because the equipment is portable and is equipped with its own handcart, there were no elaborate installation requirements. There must be adequate space for the unit and a 115-volt electrical outlet (see Section 4.4), in addition to two containers of sufficient volume to hold the as-drained and purified oils.

### *5.2.2 Training*

Training at NAS Patuxent River and NAS Jacksonville consisted of hands-on use of the equipment instructed by NAVAIR Lakehurst personnel. A Daily Operating Procedure was developed by PPEP as an additional instructional tool for operators during Phase II. A copy of the Daily Operating Procedure can be found in Appendix A.

### *5.2.3 Repairs and Maintainability*

#### 5.2.3.1 Repairs

The HTFPU at NAS Jacksonville experienced an oil leak. According to the vendor, this problem was due to improper spacing between the pump and motor shafts. A gap of at least 1/16 inch is required. If the gap is too tight (tighter than hand tightened), the mechanical seal will degrade, causing the gasket to leak. The replacement part is noted in the Allen Filter Parts and Operational manual and costs $42.05. NAVAIR Lakehurst performed the repair.

#### 5.2.3.2 Maintainability

When the difference between the pressure in the Upper Pressure line and the Lower Pressure line is greater than 35 psig, a filter change may be required. No filter changes were required during the testing period, nor was any standard maintenance.

### *5.2.4 Interface with Site Operations*

During the test period, the HTFPU was perceived as a disruption to normal operations because purified oil has not yet been approved for reuse in aircraft. Instead of draining the oil and sending it directly for disposal, operators were required to pump the drained oil through the purifier prior to disposal during the test period. As stated earlier, pumping 5 gallons of oil through the purifier for three passes took about 30 minutes, thus extending the time to perform an oil change.

Upon approval of a platform to reuse the purified oil, the equipment would be perceived as beneficial because it would reduce or eliminate the need for replacement oil. Additionally, it may possible for the HTFPU to be modified so that there is direct flow from the gearbox to the purifier and back into the gearbox, thus eliminating the need to drain the oil into a container. Regardless, a quality assurance sampling program and standard operating procedures will need to be established to ensure that the oil meets required lubrication properties.

### *5.2.5 Overall Performance*

The unit performed very well by successfully reducing the water concentration and sediment values in oil. However, the unit will not be of use to the fleet until PMA approval to reuse purified oil in the gearbox can be obtained.

## 5.3 Project Costs

The following tables represent equipment costs incurred during implementation of this project. Please note these costs are not necessarily the same as the capital costs used in the cost analysis because capital costs reflect the costs for the recommended options, not necessarily the options ordered or the modifications made for this project.

**Phase I Equipment Costs (Laboratory Testing)**

| Item | Quantity | Unit Cost | Extended Cost |
|---|---|---|---|
| Allen Filter Model VP30-1S | 1 | 3550.00 | $3,550.00 |
| Filters (<50ppm) | 1 | 530.00 | 530.00 |
| Shipping (purifier and filters) | 1 | 262.90 | 262.90 |
| | | Total Equipment Cost | $4,342.90 |

**Phase II Equipment Costs (Field Testing)**

| Item | Quantity | Unit Cost | Extended Cost |
|---|---|---|---|
| Allen Filter Model VP30-1S, including filters | 1 | 3990.00 | $3,990.00 |
| Shipping (purifier and filters) | 1 | 262.90 | 252.97 |
| | | Total Equipment Cost | $4,242.97 |

## 6.0 RECOMMENDATIONS, LESSONS LEARNED, AND FUTURE USES

It is recommended that the filter manufacturer conduct the filtration ratio test described in SAE ARP 1827 to determine a Beta rating for the filter because AIR-4.4.5 testing indicated that the current rating for particulate removal may be in error. In addition, it is recommended that a water-in-oil analyzer be used in conjunction with the HTPFU so field personnel can verify water reduction and judge whether the oil requires additional passes through the HTFPU.

Before an HTFPU would be ready for field use, several changes to the standard unit would be required. The modifications made to valves and fittings during the test program should be incorporated into the final design of the unit to make operation easier. The current configuration of the portable handcart is unstable; it should be correctly balanced and made more durable for field use. If the unit is deployed to the fleet, initial training must ensure that the users are aware of the potential for overtightening the gasket between the pump and motor shafts of the HTFPU. Overtightening could potentially cause leakage. As an alternative to the modifications described above, a system that does not require the use of two containers would be preferable in order to minimize effort in the field. In particular, a configuration that allows direct flow from the gearbox to the purifier and back into the gearbox without the need to drain the oil into a container, may be of value.

For the HTFPU to be used on any given aircraft platform, PMA approval will be required. Additionally, strict standard operating procedures will need to be established to ensure that the purified oil maintains all lubricating properties required for safe and proper operation of the aircraft. These quality assurance measures must also eliminate the potential for the purified oil to become contaminated by other fluids.

## 7.0 CONCLUSIONS

The HTFPU evaluated during this project appears to have the potential to reduce material use and waste disposal costs. The HTFPU demonstrated the ability to reduce the water content and particulates from tested samples. The cost analysis for ashore locations showed a ten-year return on investment of $3,495 and a break-even point of 5.5 years. The cost analysis for detachments showed a 10-year return on investment of approximately $38,650 and a break-even point of just over 1 year.

If purified oil is approved for reuse in aircraft by the platform PMAs, the HTFPU will be a beneficial piece of equipment for helicopter squadrons. Appropriate standard operating procedures will be necessary. At this time, Phase III testing is ongoing. As Phase III progresses, addenda describing the results will be posted to the PPEP Web Site.